PERFORMANCE EVALUATION AND CAPACITY ASSESSMENT OF A CETP FOR METAL PLATING INDUSTRIES

A Thesis submitted to

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY, PATIALA

in partial fulfillment of the requirements
For the award of degree of

MASTER OF TECHNOLOGY
in

ENVIRONMENTAL SCIENCES & TECHNOLOGY

by

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June 2006

CERTIFICATE

This is to certify that the thesis entitled "***Performance evaluation and capacity assessment of CETP for Metal plaiting industries***" submitted by Mr. VIKAS SINGH in partial fulfillment of the requirements for the award of degree of **MASTER of TECHNOLOGY in ENVIRONMENTAL SCIENCES & TECHNOLOGY** to Thapar Institute of Engineering & Technology (Deemed University), Patiala, is a record of student's own work carried by him under my supervision and guidance. The report has not been submitted for the award of any other degree or certificate in this or other university or institute till now.

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DECLARATION

I here by declare, that the thesis report entitled, ***"Performance evaluation and capacity assessment of a CETP for metal plating industries"*** written and submitted by me to Thapar Institute of Engineering & Technology (Deemed University), Patiala, in partial fulfillment of the requirements for the degree of **MASTER of TECHNOLOGY in ENVIRONMENTAL SCIENCES & TECHNOLOGY**. This is my original work & conclusions drawn are based on material collected by me.

I further declare that this work has not been submitted to this or any other university till now for the award of any other degree, diploma or equivalent course.

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ACKNOWLEDGEMENT

I wish to express my deep gratitude to Dr. A.S. Reddy, Asst. Professor, Department of Biotech. & Env. Sciences, Thapar Institute of Engineering & Technology, Patiala for his invaluable guidance, inspiration valuable suggestions, encouragement during the entire period of present study. I will not hesitate to express sincere thanks to Satluj monitoring project (SMP) staff for providing me help to perform the Lab experiment works.

I am also very thankful to faculty of Department of Biotech. & Env. Sciences, Thapar Institute of Engineering & Technology, Patiala for giving the important suggestions at the time of monitoring seminars.

Lastly, I am thankful to my colleagues, friends and family members for bearing me and providing me all moral help during the entire period of my work.

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CHAPTER 1: INTRODUCTION

1.1 Background

vvA small-scale industrial unit (SSI) is defined as any industry whose plant and machinery are valued at less that 1 crore (Government of India is planning to increase this to 5 crores) [38]. SSI occupies an important place in Indian economy for their contribution to industrial production, exports and employment. Government policies have been biased toward SSI, even though small industries are highly polluting. SSIs contribute 40% of the total industrial output of the country. But generate over 44% of the hazardous wastes while contribution by the large-scale industry is 13% [43]. Quantity of waste generated by individual SSIs may not be large, but combined effect of operation of a large number of SSI units on the environment can be high, especially when they are clustered in certain locations closer to residential or commercial centers [45, 46].

Effluents generated by SSIs need treatment prior to disposal in order to comply with the prescribed effluent standards. SSIs face many difficulties to treat their wastes by themselves. Being small, installation and use of on-site effluent treatment facilities would not be efficient, in both environmental and economic terms. Further, SSIs may not have enough budget for the creation and effective use of the facilities. Availability of space to install the facilities may be a problem for many SSIs. Most SSIs can not have trained and dedicated manpower for effectively operating and using their facilities [21].

Common facilities and common effluent treatment plant (CETP) is widely believed as solution to the effluents problem for clusters of SSIs. World Bank under its "Pollution Prevention Programme" is promoting CETPs as a viable solution to control industrial pollution[52]. Further, in many cases, the courts have given the ruling to abate the pollution problems of SSIs through using the CETP concept [23]. Many CETPs have been installed and operated all over the country for tackling the water pollution problems arising from the clusters of SSIs.

All is not well even with the CETPs. There are very few CETPs, which have been successful in tackling the water pollution problems from SSIs. Heterogenous nature of the effluent generated by different units of the cluster is seen as one of the major causes for the failure. Treatment units employed in the CETP are usually found wanting for taking care of a wide variety of pollutants present in the combined effluent that too in diluted form. Inappropriate mechanisms of cost sharing, non-conformance of the contributing SSIs with the contracted effluent contribution, inability to recover the costs of treatment, etc., have been identified as the other causes for the failure of CETPs [18].

In the present study an effort has been made to evaluate one of the CETPs provided for the treatment of effluent generated by a cluster of small-scale electroplating units. The study was limited to the following:

- Assessment appropriateness of the CETP provided vis-à-vis the SSIs being served
- Evaluation of the performance of the CETP
- Review of the design and assessment of the capacity

1.2 Objectives and scope

Objectives of the present study can be explicitely stated as the following:

- To review design of the constituent facilities of the CETP, and assess its capacity and appropriateness for the effluent in question
- To monitor performance of the CETP and assess its capability to consistently comply with the applicable effluent standards

The study included

- Understanding the industrial units contributing wastewater to the CETP
- Review of all the constituent facilities of the CETP and
- Running the CETP as per the instructions of the supplier of the CETP.

However, financial arrangements, organizational setup, and resources for the operation and maintenance of the CETP have not been included in the scope of the study.

1.3 Contents of the report

This M.Tech. Dissertation includes seven Chapters.

Chapter 1 is introduction. It provides a brief background information and deals with the objectives and scope of the study. Overview of the contents of the report and importance and limitations of the present study are also included in this chapter.

Chapter 2 is literature review. The literature is presented on the following topics

- CETPs and their performance
- Legal requirements
- Effluents from electroplating industry and their treatment

Methodology followed for the present study is described in Chapter 3.

Chapter 4 deals with the detailed description of the CETP in question.

Chapter 5 is results of the performance evaluation study.

Chapter 6 is discussion and recommendations. Here, performance of the CETP is discussed and suggestions for improving the performance are made. Comments regarding the capacity assessment are also included in this chapter.

Chapter 7 is conclusions.

1.4 Usefulness and limitations of the study

This study is supposed to provide hands on experience to the student relating to the operation and control of the CETP. The CETP is reviewed in the light of the problems faced by other CETPs of the country and solutions for some of the problems are found. Personnel of the CETP are benefited by the technical know how about the CETP and its operation and control. The study is another case study of CETP, which brought into light a few new problems.

Results of the present study and recommendations made may have to be appreciated in the light of the following limitations:

- Performance evaluation could not be carried at the full capacity while the CETP is in continuous operation.
- Some of the facilities of the CETP could not be run at all.
- Sufficient background information about the contributing industries and their effluents was not available.

CHAPTER 2: REVIEW OF LITERATURE

2.1 Introduction

Review of literature has been carried out on the following aspects:

- CETPs and their performance
- Legal requirements
- Effluents from electroplating industry and their treatment

This chapter provides brief overview of the work done in this area.

2.2 CETPs and their performance

2.2.1 Concept of CETPs [3]

Concept of common effluent treatment plant (CETP) was originally promoted by the Ministry of Environment and Forests (MOEF) in 1984 for the treatment of wastewaters from a large number of small and medium scale industries. Most of the small-scale industrial units cannot individually afford to set-up their own effluent treatment plants to meet the prescribed pollution control norms. This has been responsible for the origination of the concept of CETP. According this, a cluster of small-scale industrial units through their collective effort installs and operates a CETP for the treatment of the effluents they generate. This concept is similar to the concept of Municipal Sewage treatment plant for the treatment of sewage from all the individual houses of a municipality.

Main objective of a CETP is to reduce the treatment cost to individual units. Following are some of the other benefits associated with CETPs:

- Solving the problem of lack of technical assistance and trained personnel
- Solving the problem of lack of space
- Reduced problems of monitoring for the pollution control boards
- Organized disposal of treated wastes and sludge
- Improved waste recycling and reuse possibilities

2.2.3 Status of CETP's in India

CETP in Jeedimetla near Hyderabad (Andhra Pradesh) was the first CETP to come in to operation in India in the year 1985. As on 2000 there were 88 CETPs in India [3]. State-wise break up of these is given in **table-2.1**.

Environmental enforcement in Indian industries has been adhoc and generally ineffective. A sanction-based strategy is used to enforce environmental standards. Present policies in this regard have severe limitations and are proving counterproductive to the long-term environmental management. A solution, according to **Nandini Dasgupta [2000] [6],** to these problems may be a participatory and interactive approach to enforcement backed by a package of incentives and penalties. Cost function estimates for CETPs by **Bishwanath (2001) [16]** provide evidence of significant scale economies and high marginal abatement cost in wastewater treatment by small-scale factories.

Ramakrishna1 [2000] [44] has attempted to assess potential causes for the improper waste management by Industry and made a few suggestions with regards to the role and responsibility of the Statutory Boards in discharging their duties. He also emphasized the need and importance of co-ordination among the polluting industries, the local administration, the regulatory agencies and the public.

Pathe *et al.* [2004] [40] was evaluated performance of an existing CETP serving a cluster of small scale tanneries and suggested measures and modifications for improving the performance. The participating tanneries share operation and maintenance expenses of the CETP

Accodring to **Kathuria [2003] [18],** mere supply of an institution does not ensure sustainability of a CETP. Sustainability of a CETP actually hinges on: low rate of time discount, less rewards for defection and high degree of mutual trust among players. In Kundli, Gujrat, arrangements made for the sustained use of CETP have collapsed within 3 years and the CETP was converted to a sewage treatment plant. The author has analysed the factors that triggered the collapse of the CETP and highlighted the lessons learnt.

Whether a CETP is a solution or a problem in itself was discussed by **Maheswari and Dubey [2000]** **[23]**. Heterogeneous nature of effluents from different industries, changing nature of effluent, presence of many toxic substances, like organochlorines, polychlorinated biphenyls (PCBs) and heavy metals, in the effluents, prescribed standards being silent about the toxic chemicals and other volatile fugitives present in the effluents have been some of the reasons for the failure of the CETPs. According to the authors, the CETP concept has also faced many operational and institutional problems. Further, with the growing pace of industrialization the CETPs have become inadequate to cater to the need of the industrial clusters.

Eswaramoorthi *et al.* (2004*)* **[14]** have studied performance of a CETP at Manickapuram-pudur, Tirupur, which is handling dying effluent from over 900 small-sclae dying units, and found that the treated effluent, except for TDS, is in compliance with the effluent discharge norms of the Tamil Nadu Pollution Control Board. The authors have suggested a multitude of technologies, such as the following, for tackling the water pollution problems:

- Reverse osmosis for water reuse
- nano-filtration for salt recovery
- Multiple effect evaporator and solar evaporation ponds for reject management

Kurian (2004) **[19, 20]**, in the context of the Manikkapuram-pudur CETP, suggested Cleaner Production (CP) approach for tackling the two principal issues of concern, namely, TDS and colour. A combination of low material to liquor ratio dyeing machines and low salt (LS) reactive dyes along with dye bath segregation according to the author would reduce the salt consumption and TDS to 50% of its original level in the effluents.

Pophali *et al.* [2003] **[42]** have studied the influence of hydraulic shock loads and total dissolved solids (TDS) on the performance of three large-scale common effluent treatment plants (CETPs) of Rajasthan (two at Pali and one at Balotra) treating textile effluents.

Vinod Tare *et al.* (2003) **[48]** compared cost and quality of treatment of tannery wastewater by two CETPs both serving tannery clusters in Uttar Pradesh. One CETP is at

Jajmau and it is UASB based. The other one is at Unnao and it is activated sludge treatment process. Against the general perception, the ASP-based plant was found superior to the UASB based plant.

2.3 Legal requirements

Requirements to be complied with by the CETP may include the following:

1. Consent (for establishing, for operating and for continuing to operate) under the water (prevention and control of pollution) act, 1974 [33].
2. Authorization of the State Pollution Control Board (SPCB) under the Hazardous wastes (management and handling) rules, 1989 [37].
3. Discharge/effluent standards prescribed under the Environment (protection) rules, 1986 [28] (details in **tables-2.2, 2.3 and 2.4)**.
4. Standards prescribed for DG sets (which may be used as captive power units) under the Environment (protection) Rules, 1986 [29] (details in **table-2.5**).
5. Annual environmental statement under the Environment (protection) Rules [28], 1986.
6. Installation of water meters as prescribed under the Water (prevention and control of pollution) Cess Rules, 1977 [34, 35].
7. Submission of water consumption returns to the prescribed authority under the Water (prevention and control of pollution) cess rules, 1977 [34, 35].
8. Maintenance of hazardous waste records under the Hazardous wastes (management and handling) rules, 1989 [37, 30].
9. Compliance with the requirements related to handling of hazardous chemicals under the Manufacture, storage and import of hazardous chemicals rules, [31, 32] 1989.
10. Inspections of the regulatory agencies under the water act, 1974 and Environmental (protection) act, 1986 [36].

11. Compliance with the provisions of the Noise pollution (regulation and control) rules, 2000 [27]. Please see **table-2.6**.

2.4 Operations of metal finishing industry and effluent generation

Operations typical of metal finishing industry are listed in **table-2.6.** [9] Typical process flow scheme of an electroplating industry is shown in **table-2.7** [7].

2.4.1 Surface preparation and cleaning operations

Abrasive cleaning: Abrasives, such as rough fabric scrubbing pads, sand paper and blasting equipment, are used here for cleaning. Sand blasting (blasting with sand) is employed to remove chipped and rusted paint from metal object. This process may require cleanup and disposal of sand and paint as hazardous waste [17].

Degreasing: In this operation, organic solvents, such as aliphatic petroleum, aromatics, oxygenated hydrocarbons, and halogenated hydrocarbons, are applied on the metal surface for the dissolving and removal of oil and grease. Solvents can be used either in liquid form or in or vapor form for the oil and grease removal. Solvents used in the vapor form are more effective and efficient to their liquid equivalents in degreasing [5, 50]. The application of an emulsion containing organic solvents (e.g. kerosene, mineral oil or glycols) dispersed in an aqueous medium by an emulsifying agent, is another way to degrease metallic surfaces. Fewer chemicals are used in an emulsion of this type and the solvent concentration is lower, rendering it a preferred technique from an environmental viewpoint [10].

Soaking in alkaline cleaners: Alkaline cleaning solutions containing builders (sodium salts of phosphates, carbonates, silicates and hydroxides) and surfactants are employed to remove soil, old plating, paint, etc., from surfaces.

Acid cleaning and pickling: Acidic cleaning solutions may contain mineral acids (nitric, sulfuric and hydrochloric) or organic acids (sulfamic, acetic, oxalic or cresylic) and are used to remove rust and scale [9].

Electro-cleaning: Electro-cleaning is a good method for the removal of particulate matter and can be combined with other cleaning techniques to obtain better results. This technique makes use of direct, reverse, or periodically reversed electric current for the removal of soil and smut and, activation of the metallic surface. The work piece may be set up as cathode or anode. Electro-cleaning baths contain a solution with ingredients similar to those of alkaline cleaning and can be operated either at ambient temperature or in the range 40-80°C [50].

Ultrasonic cleaning: An ultrasonic source is used for removing particulate matter by creating a mechanical activity, which is usually combined with a chemical activity to accelerate the cleaning process. Ultrasonic cleaning may be carried out in an aqueous or organic medium, the latter being ideal for the removal of finely divided solid particles. Since ultrasound travels in all directions in the solution, it can reach areas of the work piece that are otherwise inaccessible. This is particularly useful for cleaning parts with complex geometry, thus bringing substantial value to precision cleaning applications. Also, ultrasonic cleaning is faster and more uniform than other conventional cleaning methods. It reduces the use of hazardous chemicals and is compliant with safety and environmental regulations.

2.4.2 Surface finishing operations

Electroplating: Electroplating involves deposition of a thin surface coating of metal by electrolytic process upon the job surface. Commonly electroplated metals and alloys include brass, cadmium, chromium, copper, gold, nickel, silver, tin and zinc. Electroplating baths may be acidic, alkaline, or neutral solutions, containing metal ions that are reduced under the influence of an electrical current, depositing free metal on the cathodic surfaces of the workpiece being plated. A complexing agent, usually sodium or potassium cyanide, is placed in the bath for electroplating cadmium and precious metals, and to a lesser degree, for copper and zinc electroplating [10, 50].

Anodizing: This process leads to the formation of an insoluble oxide layer on the surface of the job. Here the job is placed as an anode in an electrolytic solution [Christie 1998] Anodizing is commercially applied only to aluminum base metal. The electrolyte used can be chromic, oxalic, phosphoric or sulfuric acid (sulfuric acid based solution is commonly used) [50].

Chemical conversion coating: Chemical and electrical conversion processes deposit a protective and/or decorative coating on a metal surface. These processes include phosphating, chromating, passivation, and metal coloring. Please see **table-2.8** for details.

Immersion plating: Immersion plating involves deposition of a very thin metal layer from a metal salt solution onto the surface of a base metal without using reducing agents or electrical current. This plating requires that the base metal should have higher oxidation potential. Coating occurs through metal displacement process. By immersion plating many metals, including aluminum, copper alloys, steel, brass, bronze, cadmium, copper, gold, lead, nickel, palladium, rhodium, ruthenium, silver, tin, and zinc are plated [50].

Electroless plating: Electroless plating can be performed on metals as well as non-metals. In this process the metal coating is chemically deposited on the workpiece by immersing in the plating solution without any use of electric current. Here the metallic ions are reduced to free metal and deposited onto the workpiece surface. A catalyst is needed to induce this plating process. Additionally, reducing and complexing agents as well as stabilizers are also needed in the plating process [10]. Precise control of metallic salt concentration, temperature, and pH are important for optimal results.

Painting: Painting involves providing a thin organic layer over the job's surface. Varnish, lacquer, shellac or plastic coating are applied in one of several forms, including dry powder, solvent-diluted and water-borne forms. Paint application methods may include spraying, dipping, brushing, roll coating and wiping [5, 10].

2.4.3 Rinsing

Rinsing operations essentially remove clinging films of process solutions from a workpiece by substituting a safe film of water, thus producing the largest volume of effluent from metal finishing operations. The workpieces need proper rinsing between treatment stages in order to avoid the problems of staining and subsequent process contamination [8]. Rinsing operations make use of demineralized water or tap water. Different types of rinsing methods are in use. Efficient rinsing schemes are those that achieve the desired results while expending as little effort as possible and consuming as minimum as possible of water.

2.5 Wastewaters from electroplating industry

2.5.1 Wastewaters and their sources

Wastewaters generated by metal finishing industry are shown in **table-2.9**. Contaminants expected in the wastewaters from metal finishing industry are shown in **table-2.10**.

Watson [51] distinguished the wastewater generated in the electroplating and metal finishing industry as following:

1. Rinse water from surface finishing operations.
2. Concentrated plating and finishing baths that are intentionally or accidentally discharged.
3. Wastes from plant or equipment cleanup.
4. Sludges, filter cakes, etc., produced by naturally occurring deposition in operating baths or by intentional precipitation in the purification of operating baths, chemical rinsing circuits, etc., when flushed down sewers.

Electroplating bath solutions are periodically disposed of whenever their composition reaches a state where it may not be readjusted to operable limits. They are normally discharged in effluent streams as contaminated wastewaters. The resulting wastewaters contain high concentration of caustics, acids, solvents, and organic chemicals [49].

Wastewaters containing cyanide salts and chromates are of much concern because they are highly toxic for humans and aquatic life even in low concentration. Despite this, since cyanide salts yield brighter and less porous metal plating finishes, they are expected to remain widely in use [7].

Degreasing operations may result in solvent bearing wastewater and material in solid form. Chemical surface treatment operations can result in wastes containing metals.

Alkaline, acid, and abrasive cleaning methods can generate waste streams such as spent cleaning media, wastewater and rinse water. These wastes usually contain metal complexes or particles, cleaning compounds, and contaminants from the metal surface. Wastewater generated by cleaning operations is primarily rinsing water [10].

Wastewater from stripping are acidic in nature and consist of solutions of sulfuric, nitric, and hydrochloric acid, and also alkaline sometimes.

2.5.2 In-plant wastewater minimization strategies

In-plant waste **minimization** strategies employed for minimizing volume or strength of the wastewaters generated and for eliminating priority and difficult pollutants from the wastewaters are shown in **table-2.11** explained in-plant waste minimization techniques and strategies at greater detail.

For metal plating industries, **Braum (2004)** [2] suggested implementation and use of a combination of techniques (environmental auditing; cleaner production; formation of and co-operation between industry associations and local authority; waste minimization groups; cost based incentives; and structured enforcement of the bylaws and agreements) to reduce the environmental impacts.

2.6 Wastewater treatment technologies for electroplating industry

Contaminants expected in the effluents from metal finishing industry are shown in **table-2.10**. Different streams of wastewaters from metal finishing industry are often not compatible for mixing for treatment and disposal. Such indiscriminate mixing actually affects treatability of the wastewater. Certain streams of wastewater, specially cyanide containing wastewater and hexa-valent chromium containing wastewaters, require pretreatment prior to mixing with other wastewater streams for treatment and disposal. Physical and chemical treatment processes, such as, neutralization, de-emulsification, precipitation and settling, are used, in most of the cases, for the treatment of metal finishing industry effluents. Wastewaters, in most of the cases are not polluted by biodegradable organic matter. Further, the wastewater may contain many toxic and inhibitory substances. Hence, biological treatment processes are usually not used in the treatment of metal finishing industry effluents [39]. Please **table-2.12** for the treatment technologies employed in the treatment of effluents from metal finishing industry.

2.6.1 Pretreatment

Hexavalent chromium reduction: wastewater streams suspected to contain hexavalent chromium are segregated and treated for reduced the hexavalent chromium into tri-valent chromium and then the wastewater is combined with other wastewater streams for further treatment. Chromium reduction is achieved by addition of sulfur oxide gas or sodium metabisulfite at pH between 2.0 and 3.0 **[11]**.

Cyanide oxidation: Cyanide wastewater flow is treated by an alkaline chlorination process for oxidation of cyanides into carbon dioxide and nitrogen. This treatment is provided prior to the removal of metals from the wastewater. Usually two reaction tanks are used for brining about the cyanide oxidation. In the first tank, conditions are adjusted, to oxidize cyanides into cyanates, by introducing chlorine and caustic and maintaining pH in the range of 9.5 to 10.0. Chlorine is typically added as chlorine gas or sodium hypochlorite. In the second reaction tank, conditions suitable for oxidizing cyanate into carbon dioxide and nitrogen are maintained by dosing additional chlorine and adequate caustic and maintaining a pH of 8.0. wastewater may require about 45 minutes detention time in each of these tanks.

Oily waste de-emulsification: Sulfuric acid, polyelectrolyte, alum, calcium chloride are used in the de-emulsification process. The de-emulsified oil is removed from the wastewater by multitude of techniques including skimming, flotation, centrifugation and ultra filtration.

2.6.2 Primary treatment

Hydroxide precipitation: This is accomplished by adjusting pH of the wastewater with an alkaline reagent. At alkaline pH solubility of the metals is reduced and metal hydroxide precipitates are formed. The metals can also be removed in the form of metal carbonates. For this, chemicals, like, soda ash (Na_2CO_3), sodium bicarbonate [$Na(HCO_3)_2$], calcium carbonate ($CaCO_3$), etc. are used. The precipitates formed are removed by settling in clarifiers. Please see **table-2.12** for details. Flocculating agents are often added for the improved removal of precipitated metal hydroxide. The settled metal hydroxide sludge is thickened, dewatered and dried by mechanical or thermal means.

Filter presses, sludge drying beds, etc., are used in the sludge dewatering and drying operations. Chemical conditioning improves sludge dewatering. Choice of chemical conditioners is very much dependent on the characteristics of the sludges and the type of dewatering devices. Lime, alum, ferric chloride and polyelectrolytes are commonly used chemical conditioners. Clarified wastewater can be further processed by filtration through a sand bed or multimedia filter for removing fine metal hydroxide flocs [4].

Sulfide precipitation: One of the serious problems in hydroxide precipitation is contamination of plating wastewaters with ammonia, ethylenediaminetetraacetic acid (EDTA), phosphates, and tartrates are commonly used in plating operations. These compounds (called chelates) combine with the dissolved metal ions to form complex ions which are soluble in neutral or alkaline solutions. Sulfide precipitation helps in precipitating out metals as sulfides. In such problem cases, sulfide precipitation method can be employed for lowering the metal solubility and removing metals as metal sulfide precipitates. In this process, precipitating agents, such as, sodium sulfide (Na_2S), sodium hydrosulfide (NaHS), ferrous sulfide (FeS) and calcium sulfide (CaS) are used.

Use of metal sulphide instead of hydroxide precipitation results in high degree of metal removal at relatively low pH values. Sulphide precipitates are sparingly soluble in nature, the formed sulfides have favourable dewatering characteristics and stability [4]. However, metal sulphide precipitation route suffers from the following problems:

- Formation of fine particles
- Formation of aqueous polysulphide complexes, which consume the sulphide reagent and compromise the metal removal

Treatment efficiencies that can be achieved through precipitation removal of various metals are shown in **table-2.13**.

2.6.3 Secondary treatment: For metal finishing industry secondary treatment is usually not required. But in some industries for better and efficient removal of metals, secondary or biological treatment is used after primary treatment. Bio-film reactors, trickling filters, and activated sludge process (ASP) are mainly used for secondary treatment. In this process mainly metal absorption takes place [22].

Treatment of wastewaters containing small amounts of refractory organic pollutants, such as anionic surfactants, small amounts of heavy metals, such as cupric and chromic ions, and large amounts of sodium salts by biofilm activated carbon have been reported by **Yoshitake Suzuki *et al*. [1996]** [47]. About 50% of the organic substances and about 80% and 30%, respectively of the ionic species of copper and chromium were removed from the wastewater. The heavy metals were removed by uptake into the bodies of microorganisms, while organic substances were removed by biological decomposition.

Table-2.1: CETPs in India

S.No.	Name of the state/UT	No. of CETPs
1	Andhra Pradesh	3
2	Delhi	15
3	Gujrat	7
4	Himachal Pradesh	4
5	Haryana	1
6	Karnataka	3
7	Madhya Pradesh	3
8	Maharastra	8
9	Punjab	4
10	Rajasthan	2
11	Tamil Nadu	36
12	Uttar Pradesh	2

Source: Ministry of Environment and Forests

Table-2.2: Electroplating Industries

Parameters	**Concentration not to exceed mg/L (except for pH and temperature)**
pH	0.6 to 9.0
Temperature	Shall not exceed 5°C above the ambient temperature of the receiving body.
Oil and Grease	10
Suspended Solids	100
Cyanide (as CN)	0.2
Ammonical Nitrogen (as N)	50
Total Residual Chlorides (as Cl)	1.0
Cadmium (as Cd)	2.0
Nickel (as Ni)	3.0
Zinc (as Zn)	5.0
Hexavalent Chromium (as Cr)	0.1
Total Chromium (as Cr)	2.0
Copper (as Cu)	3.0
Lead (as Pb)	0.1
Iron (as Fe)	3.0
Total Metal	10.0

Source: Ministry of Environment and Forests

Table-2.3: common effluent treatment plants: Primary Treatment Effluents

Parameters	**Concentration in mg/l**
pH	5.5 – 9.0
Temperature °C	45
Oil & Grease	20
Phenolic Chompunds (as C_6H_5OH)	5.0
Ammonical Nitrogen (as N)	50
Cyanide (as CN)	2.0
Chromium Hexavalent (as Cr+6)	2.0
Chromium (total as Cr)	2.0
Copper (as Cu)	3.0
Lead (as Pb)	1.0
Nickel (as Ni)	3.0
Zinc (as Zn)	15
Arsenic (as As)	0.2
Mercury (as Hg)	0.01
Cadmium (as Cd)	1.0
Selenium (as Se)	0.05
Fluoride (as F)	15
Boron (as B)	2.0
Radioactive Materials	
Alpha emitters, Hc/ml	10-7
Beta emitters, He/ml	10-8

Note:

1. These standards apply to the small scale industries, i.e. total discharge upto 25 Kl/Day.
2. For each CETP and its constituent units, the State Board will prescribe standards as per the local needs and conditions; these can be more stringent than those prescribed above. However, in case of clusters of units, the State Board with the concurrence of CPCB in writing may prescribe suitable limits.

Source: Ministry of Environment and Forests

Table-2.4: Treated Effluent Quality of Common Effluent Treatment Plant

Parameters	**Into inland surface waters**	**On land or irrigation**	**Into Marine Coastal areas**
pH	5.5 – 9.0	5.5 – 9.0	5.5 – 9.0
BOD (5 at 20$_o$C)	30	100	100
Oil and grease	10	10	20
Temperature	Shall not exceed 40°C in any section of the stream within 15 meters downstream form the effluent outlet	---	45°C at the point of discharge
Suspended Solids	100	200	(a) For process waste-waters –100 (b)For cooling water effluents 10% above total suspended matter of effluent cooling water.
Dissolved Solids (Inorganic)	2100	2100	---
Total residual chlorine	1.0	---	1.0
Ammonical nitrogen (as N)	50	---	50
Total Kjeldahl nitrogen (as N)	100	---	100
Chemical Oxygen Demand	250	---	250
Arsenic (as As)	0.2	0.2	0.2
Mercury (as Hg)	0.01	---	0.01
Lead (as Pb)	0.1	---	1.0
Cadmium (as Cd)	1.0	---	2.0
Total Chromium (as Cr)	2.0	---	2.0

Table 2.4: (contd..)

Copper (as Cu)	3.0	---	3.0
Zinc (as Zn)	5.0	---	15
Selenium (as Se)	0.05	---	0.05
Nickel (as Ni)	3.0	---	5.0
Boron (as B)	2.0	2.0	---
Percent Sodium	---	60	---
Cyanide (as Cn)	0.2	0.2	0.2
Chloride (as Cl)	1000	600	---
Fluoride (as F)	2.0	---	15
Sulphate (as SO_4)	1000	1000	---
Sulphide (as S)	2.8	---	5.0
Pesticides	Absent	Absent	Absent
Phenolic compounds (as C_6H_5OH)	1.0	---	5.0

Note: All efforts should be made to remove colour and unpleasant odour as far as possible

Source: Ministry of Environment and Forests

Table-2.5: The emission limits for new diesel engines upto 800 kW for generator sets

Capacity of diesel engines	Date of implementation	Emission Limits (g/kw-hr) for				Smoke Limit (light absorption coefficient, m -1) (at full load)	Test Cycle	
		NOx	HC	CO	PM		Torque %	Weighting factors
Upto 19 kW	1.7.2004	9.2	1.3	3.85	0.3	0.7	100	0.05
							75	0.25
> 19 kW upto 176 kW	1.1.2004	9.2	1.3	5.0	0.5	0.7	50	0.30
	1.7.2004	9.2	1.3	3.5	0.3	0.7	25	0.30
> 176 kW upto 800 kW	1.7.2004	9.2	1.3	3.5	0.3	0.7	10	0.10

Noise Standards for DG sets (15-500 KVA)

- The total sound power level, of a DG set should be less than 94+10 log10 (KVA), dB (A), at the manufacturing stage.
- This level should fall by 5 dB (A) every five years, till 2001, i.e. in 2002 and then in 2007.

Source: Ministry of Environment and Forests

Table-2.6: Ambient Air Quality Standards in respect of Noise

Area Code	**Category of Area/Zone**	**Limits in dB (A) Leq ***	
		Day Time	Night Time
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	Silence Zone	50	40

Source: Ministry of Environment and Forests Rules [2000]

Table-2.7: Typical operations of metal finishing industry

Surface preparation and cleaning	Abrasive cleaning Degreasing Alkaline soaking Acidis soaking (pickling) Electrocleaning Ultrasonic cleaning
Surface finishing	Electroplating Anodizing Chemical conversion coating Immersion plating Electroless plating Painting
Rinsing	rinsing

Source: EPA (1990) [9]

Table-2.8: **A flowchart for some common plating processes**

Copper plating	**Nickel plating**	**Chrome plating**	**Chrome plating**
Electrocleaner	Electrocleaner (cathodic)	Electrocleaner (cathodic)	Electrocleaner (cathodic)
Running rinse	Electrocleaner (anodic)	Running rinse	Running rinse
Hydrochloric acid dip	Running rinse	Sulfuric acid dip	5% sulfuric acid dip
Running rinse	5% sulfuric acid dip	Running rinse + spray	Running rinse
Copper cyanide ‘strike’	Running rinse	Chrome solution	Zinc cyanide solution
Running rinse	Bright nickel solution	Recovery rinse	Running rinse
Running rinse	Running rinse	Mist spray rinse	Spray rinse
Copper Pyrophosphate Solution	Soap dip	Running rinse	Brightner still dip (HNO2)
Running rinse	Hot running rinse	Hot still dip	Running rinse
Hot rinse	Drying oven	Running rinse	Running rinse
Drying oven		Hot rinse	Hot water dip
		Drying oven	Drying oven

Source: [Eckenfelder 2000]. [7]

Table-2.9: Chemical Conversion Coating Operations

Operation	**Process**	**Purpose**	**Remarks**
Chromating	Chemical or electrochemical treatment Solution contains hexavalent chromium and anions	Impart corrosion resistance	Generally applied to aluminum, silver, cadmium, copper, zinc and magnesium
Phosphating	Chemical treatment Solution is dilute, containing phosphate salts, phosphoric acid, and other reagents	Imparts corrosion resistance Make metal surface more amenable to painting and coating	Generally applied to steel, iron, and zinc-plated steel
Metal coloring	Chemical or electrochemical treatment Coloring solution	Produce a decorative finish	
Passivating	Chemical treatment Solution is acidic, typically nitric acid or nitric acid with sodium dichromate	Forms a protective film on metals	Stainless steel products are often passivated

Sources: [EPA 1995] and [Wang 1992]. [10, 50]

Table-2.10: Sources of wastewater of metal finishing industry

Operation	**Process**	**Process wastewater**
Surface preparation and cleaning	Abrasive cleaning	No wastewater is generated
	Degreasing	Organic solvents, oil and Grease
	Soaking in alkaline cleaners	Solvent, alkaline wastes
	Acid cleaning and pickling	Solvent, acid wastes
	Electro-cleaning	Solvent, alkaline, and acid wastes
	Ultrasonic cleaning	Solvent, alkaline, and acid wastes
Surface finishing	Immersion plating	Metal, acid, and base wastes and complexing agents (such as lactic, glycolic, malic acid salts).
	Anodizing	Acid wastes
	Chemical conversion coating	Metal salts, acid, and base wastes
	- Chromating	Chromium metal, cyanide, acid, and base wastes
	- Phosphating	Phosphate Salts, Metal salts, acid, and base wastes
	- Metal coloring	Solvents, metals
	- Passivating	Acids, salts
	Electroplating	Acid/ alkaline cyanide and acid waste
	Electroless plating	Cyanide and metal wastes
	Painting	Solvent wastes
	Other metal finishing techniques	Metal and acid wastes
Rinsing	Rinsing	Solvent, alkaline, and acid wastes containing water
	Floor washing and wet cleaning operations of equipment	Detergents, Metals, Solvents, alkaline, and acid wastes

Source: [EPA 1995]. [10]

Table-2.11: Contaminants present in wastewaters from metal finishing industry

Process	**Chromium**	**Other metals**	**Cyanide**	**Oils**	**Solvents**
Polishing	*	*		*	
Solvent cleaning			*	*	
Alkaline cleaning		*	*	*	*
Pickling	*	*			
Etching	*	*			
Chromating	*	*			
Phosphating	*	*		*	
Passivating	*	*			
Plastic coating					*
Paint coating		*			*
Hot-dip coating		*			
Electroless plating		*			
Anodizing		*			
Electropolishing	*	*			
Electroplating	*	*	*		

Source: [Freeman 1995]. [15]

Table-2.12: In-plant waste minimization techniques and strategies

Chemical substitution	- Trivalent chromium for hexavalent chromium - Alloy substitutes for chromium deposits - Alkaline non-cyanide copper for cyanide copper - Bright acid chloride zinc substitute for cyanide zinc - Zincate substitute for bright cyanide solution - Mechanical zinc plating as substitute to zinc electroplating - High pH nickel substitute for copper strike - Carbon substitute for electroless copper - Copper alkaline solutions substitute to cyanide copper - Zinc alloy for cadmium plating - Non-cyanide cadmium bath substitute - Alternate gold/silver plating solutions - Sulfuric acid substitute for chromic acid in anodizing - Water-based paint substitute for solvent based paint - High-solids solvent paints for regular solvent-based paints - Miscellaneous
Reducing solvent emissions from paint applications	- Powder coating systems - Electro-deposition painting
Bath life extension	- Bath maintenance and regeneration - Solids removal
Drag-out minimization	- Maintaining low solution viscosity - Slowing withdrawal rate - Improving drainage of work piece
Rinse water volume reduction	- Using cascade rinse systems - Using valves - Increasing turbulence between work piece and rinse water

Table-2.12 (contd..)

Recycling and resource recovery	- Rinse water recycling - Evaporation - Ion exchange - Electrolytic recovery - Reverse osmosis - Ultra-filtration - Electro-dialysis - Supported liquid membrane separation - Centrifugation and pasteurization of machine coolants - Centrifugation and recycling of painting water curtains - Pervaporation

Source: Economic and social commission for western Asia (2001) [13]

Table-2.13: Conventional Chemical Treatment Method (EPA, 1995)

Treatment Method	Treatment Chemical	Optimum pH	MRT (Min)	Comments
Hexavalent chromium reduction				
Acid method	Sodium metabisulfite	3.0-3.5	5	Reaction time dependent on pH.
	Sulfur dioxide	3.0-3.5	5	Reaction time dependent on pH.
	Ferrous sulfate	3.0-3.5	5	Reaction time dependent on pH.
Cyanide oxidation				
A. Cyanide to cyanate	Chlorine gas	>11.0	10	pH>11.0 critical to prevent toxic gas.
	15% sodium hypochlorite	>11.0	10	pH>11.0 critical to prevent toxic gas.
	Calcium hypochlorite	>11.0	10	pH>11.0 critical to prevent toxic gas.
B. Cyanate to CO_2 and N_2	Chlorine gas	8.5	20	Reaction time dependent on pH.
	15% sodium hypochlorite	8.5	20	Reaction time dependent on pH.
	Calcium hypochlorite	8.5	20	Reaction time dependent on pH
Metal precipitation				
A. Hydroxide	Hydrated lime	7.0-10.0	20	Optimum pH varies depending on metal to be removed.
B. Sulfide	Caustic soda	7.0-10.0	20	Optimum pH varies depending on metal to be removed.
	Ferrous sulfide/sodium Sulfide	8.0-9.0	15	Polishing after hydroxide precipitation when complexing agents present.
C. Carbonate	Sodium bicarbonate	>7.0	15	Advantageous for lead, cadmium, nickel removal.
D.Insoluble starch xanthate	Cross linked starches		Instantaneous	Polishing after hydroxide precipitation when complexing agents present.
Oily waste de- emulsification				
Acidification/hydrolysis/ adsorption	Sulfuric acid	<3.0	10-20	Removal efficiencies related to type
	Polyelectrolyte	=3.0-5.0	10-20	Of emulsifying agent used and natural
	Alum	<3.0	10-20	Of oil (i.e., mineral based or synthetic Type).
	Calcium chloride	<3.0	10-20	Addition of heat may also need for certain applications.

Source: (EPA, 1995) [10]

Table 2.14 Process Performance Data for the Control of Cd, Cu, Pb, Ni and Zn

Metal	**Plant**	**Process**	**Average concentration of metal in the treated effluent (mg/L)**
Hydroxide precipitation			
Cadmium	Metal finishing	Lime	0.02
Copper	Metal finishing	NaOH	2.63
	Commercial TSD	Lime precip.	0.58
Lead	Electr. Components	NaOH	0.14
Nickel	Electr. Components	NaOH	0.52
	Commercial TSD	Lime	1.8
Zinc	Commercial TSD	Lime	1.05
Hydroxide precipitation in the presence of Fe/Alum			
Cadmium	Metal finishing	FeCl3 + base	0.07
	Metal finishing	FeSO4 + base	0.579
Copper	Electr. components	NaOH + FeSO4	0.17
	Electr. Components	NaOH + FeSO4	0.59
	Metal finishing	FeSO4 + hydroxide	0.505
	Commercial TSD	NaOH + FeCl3	1.2
Lead	Commercial TSD	NaOH + FeCl3	0.07
Nickel	Electr. Components de	NaOH + FeSO4	0.165
	Electr. Components	NaOH + FeSO4	0.63
	Metal finishing	FeSO4 + hydroxide	0.018
	Commercial TSD	NaOH + FeCl3	1.1
Zinc	Metal finishing	FeSO4 + hydro	0.005
	Commercial TSD	NaOH + Al coprec.	4.1
Sulfide precipitation			
Cadmium	Copper smelter	Na2S + lime	0.01
	Commercial TSD	Lime + sulfide	0.5

Table-2.14 (contd..)

Copper	Commercial TSD	Lime + sulfide	0.15
	EPA test run	Sulfide + ion exchange	2.3
Lead	Commercial TSD	Lime + sulfide	0.01
	EPA test run	FeS + ion exchange	0.5
Nickel	Commercial TSD	Lime + sulfide	0.34
Zinc	Metal finishing	FeS + ion exchange	0.5

Source: Phungrassami (2001) [41]

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter presents the methodology adopted for the study. For achieving the objectives of the study work was planned on the following work elements:

- Learning wastewater sampling and analysis techniques
- Review of literature on CETPs for metal plating industries
- Understanding the activities and operations of metal plating industry
- Detailed survey of the CETP and its various facilities and provisions
- Detailed monitoring of the CETP and performance evaluation
- Review of the design and the facilities of the CETP for capacity assessment

Approach followed for the completion of work related to the above work elements is described in this chapter.

3.2 Learning wastewater sampling and analysis techniques

Sampling and analysis techniques for the following parameters have been learnt:

- PH
- Conductivity
- Solids (total solids, total dissolved solids and total suspended solids)
- COD (chemical oxygen demand)
- BOD (biological oxygen demand)
- Kjeldahl Nitrogen (both ammonical and organic nitrogen)
- Nitrate plus nitrite nitrogen
- Total phosphorus
- Heavy metals (only preparation of sample for analysis by AAS)

- Sludge volume index
- Testing of purity of lime
- Performing jar test for pH and coagulant dose optimization

Facilities provided under the Satluj river water quality monitoring project of the Environmental Engineering laboratory have been used. Information on the analytical techniques was obtained from the APHA manual [1]. Information on the performance of jar test for optimizing pH and and coagulant dose was obtained from industrial water pollution control by W.W. Eckenfelder, Jr. (2000) [7]. Information for conducting the sludge volume index was obtained from Wastewater Engineering by Metcalf & Eddy [24, 25].

3.3 Review of literature on CETP for metal plating industries

Review of literature was limited to the years, 2000 to 2005, and concentrated on the following aspects:

- CETPs and their performance and management
- Wastewater management in electroplating industries
- Treatment of effluent from electroplating industry
- Regulatory requirements applicable to CETP and to electroplating industry

Internet search using Google search, Science direct, Yahoo search and e-library of the TIET were used for the literature search. First abstracts were reviewed and full papers of relevant literature were then obtained for literature. E-reports of USEPA [9-12] were depended on for the review of wastewater management in metal finishing industry. Environmental legislation from the website of MOEF [26, 37] was depended for knowing the effluent standards and other legal requirements applicable to the CETPs and to the metal finishing industry.

3.4 Understanding the activities & operations of metal plating industry

Initial understanding was obtained from the e-reports of the US EPA. Efforts were made to supplement this understanding by survey of 5 small-scale electroplating units that are contributing effluent to the CETP in question. The units were practicing pickling, zinc plating and chromating on the cycle parts and automobile spares. Because of the accessibility problems detailed information on the wastewater management for these units was not obtained. Similarly nothing much could be known about the pre-treatment provided to the effluent prior to its discharge into the CETP for treatment and disposal.

3.5 Detailed survey of the CETP and its various facilities and provisions

The survey was carried out over 4 visits of one-day duration each to the CETP. During the survey design drawings (specially plant layout and P&I) and operation and maintenance manual of the CETP were reviewed. Further all the facilities and provisions of the CETP were physically examined and their dimensional details and capacity details were obtained. Even operation of the CETP was also critically examined. On the basis of the survey process description and process flow diagram of the CETP was obtained. Further, monitoring and experimentation for performance evaluation of the CETP was finalized on the basis of this survey. The observed problems and deficiencies of the CETP were also recorded.

3.6 Monitoring of the CETP and performance evaluation

In the light of the problems and difficulties associated with the operation of the CETP as per the instructions of the supplier of the plant monitoring of the CETP and performance evaluation was carried out in two parts:

Part-1: collection of composite samples (at half an hour intervals over four hours) at the following four different locations of the CETP and analyzing them for the parameters identified through the review of applicable effluent standards:

- Raw effluent being pumped to the grit channels
- Equalized effluent being loaded to the reaction tanks where the effluent is being neutralized and precipitated and coagulated through dosing of lime and ferrous sulfate
- Treated primary effluent being loaded to the bio(trickling)filters

- Treated secondary effluent being discharged into the municipal sewer

The collected samples were mostly analyzed in the environmental laboratory of the TIET. However for the analysis of the samples for metals, phenolic compounds, oil and grease and cyanide, TCIRD laboratories were depended on.

Part-2: Conducting of neutralization, precipitation, flocculation and settling experiments on the equalized effluent in the Environmental laboratory of the TIET - Lime and ferrous sulfate obtained from the CETP were used in these experiments after establishing their strengths. Through the laboratory experimentation consistency and amount of the ETP sludge generated was estimated.

The results obtained from the monitoring and performance evaluation studies were compared with the effluent standards prescribed in order to assess compliance with the latter.

3.7 Review of the design of the CETP for capacity assessment

Information obtained from the following was used as input for the CETP capacity assessment

- Survey of the CETP
- Results obtained from laboratory experimentation
- Design drawings and operation and maintenance manual of the CETP

Capacity assessment was carried out for each of the individual units of the CETP. Capacity of the CETP was taken as the capacity of that unit of the CETP which has lowest capacity.

CHAPTER 4: OVERVIEW OF THE CETP

4.1 Sources of effluents to the CETP

The CETP in question is installed for the treatment of effluent from a cluster of industrial units. This CETP is receiving wastewater from as many as 46 small-scale industrial units (details in **table 4.1**). The wastewater received mainly includes the following:

- Effluents from electroplating units engaged in the zinc plating and chromating of automobile and bicycle parts
- Effluents from textile dying units
- Domestic effluents from different industrial units of the pocket

The plant is designed for the treatment of 200 m^3/hour of average flow and 400 m^3/hour of peak flow, and it is supposed to operate for 16.5 hours per day. Treated effluent of the CETP is metered and disposed into the municipal sewer.

4.2 Wastewater treatment processes of the CETP

Wastewater treatment process of the CETP is schematically shown in **figures-4.1**. Please see **table-4.2** for the dimensional and other details of the facilities of the CETP. Wastewater reaching the CETP is passed through a bar screen and collected into a wastewater recipient tank. Effluent from this tank is pumped with the help of four submersible pumps into two equalization tanks through two grit channels, each with a bar screen at the inlet end. Grit channels have provisions for the removal of floating oil and grease. With the help of three blowers contents of the equalization tanks are aerated and mixed.

With the help three pumps wastewater from the equalization tanks is pumped to two neutralization tanks wherein lime slurry and ferrous sulfate solution are dosed for neutralizing the wastewater and precipitating the metal ions present as metal hydroxides. The neutralized effluent is then dosed with polyelectrolyte solution and allowed to flow into two tube settlers for the removal of the precipitated metal hydroxide flocs and other settleable suspended solids. Neutralized effluents after clarification in the tube settlers is allowed to flow into two additional neutralization tanks for adjusting pH through dosing hydrochloric acid. Clarified effluent after pH adjustment is dosed with nutrient solution and collected into two bio-filter feed sumps.

With the help of three pumps the effluent from the bio-filter feed sumps is pumped and sprayed over the top of two bio(trickling)filters for secondary treatment and removal of soluble biodegradable organic matter. Effluent trickling down from the bio(trickling)filters is allowed to flow under gravity into two circular secondary clarifiers. These clarifiers have rotating mechanisms for scrapping the settled sludge towards the center. Clarified effluents from these clarifiers is combined, metered and allowed to drain into the municipal sewer.

Settled sludge from the tube settlers and from the secondary clarifiers is collected into a combined sludge sump under gravity. Combined sludge sump has a mechanical mixing unit for mixing the sludge. From the sludge sump with the help of two pumps the sludge is loaded into a circular sludge thickening tank. Sludge thickener also has a central rotating mechanism for scrapping the settled sludge to the centre. With the help of three screw pumps thickened sludge is loaded to two centrifugal sludge dewatering units after dosing with polyelectrolyte. Dewatered sludge is stored in the ETP sludge storage cell.

There are provisions for collecting the wastewater generated during treatment from the following three places and recycling the to the wastewater recipient tank:

- Effluent drained out during degritting of the grit channels
- Overflows of the circular sludge thickening unit
- Filtrate generated at the centrifugal sludge dewatering unit

There is also provision for the recycling of the treated final effluent back into the bio-filter feed sump.

Along with treatment chemicals storage facility for dose optimization and necessary experimentation one noncommissioned laboratory is also available in the CETP. For the power generation one Electrical power and DG set is also present.

4.3 Capacity Assessment

The CETP has been designed to treat 200 m^3/hour of wastewater. The capacity assessment has been carried out to check whether all the units of the CETP have this minimum capacity or not. If any of the units have additional capacity then how much additional capacity they have has also been checked. The assessment details are provided in the Table 4.3.

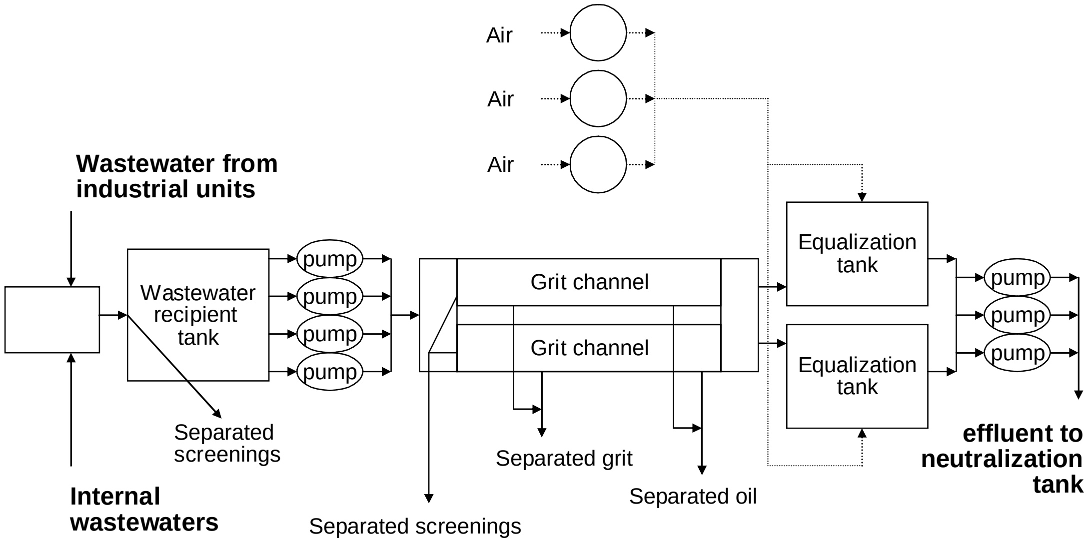

Figure-4.1: Wastewater Process of the CETP

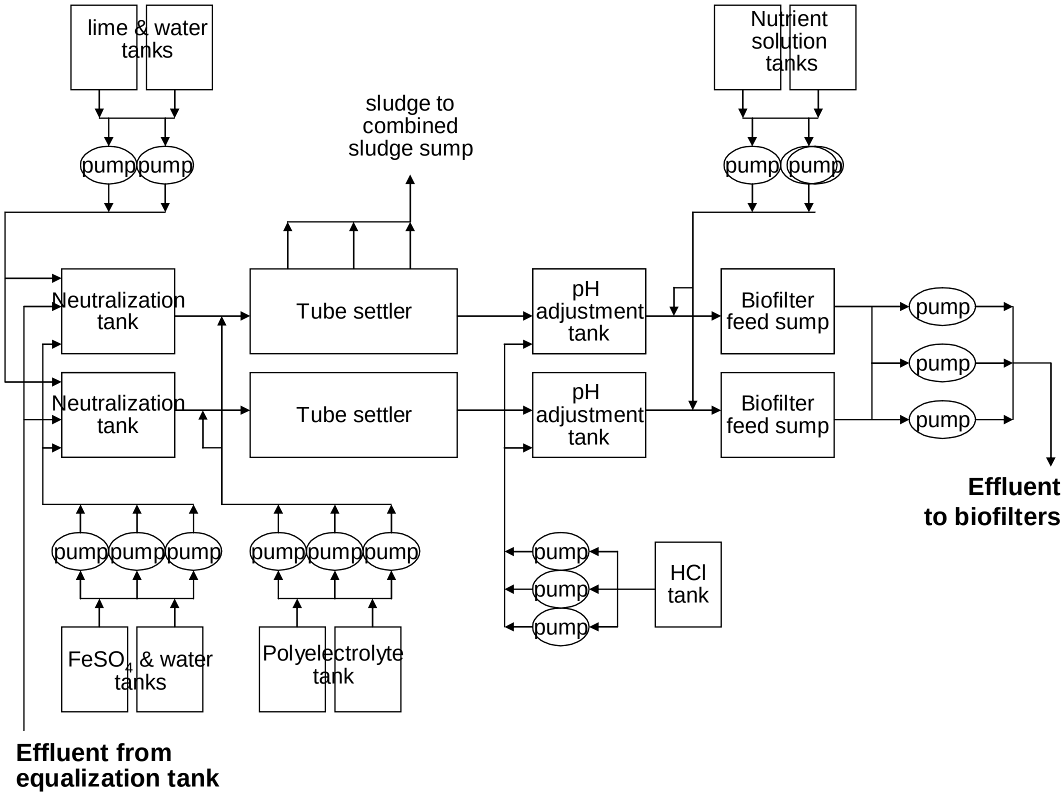

Figure-4.1: Wastewater Process of the CETP (contd..)

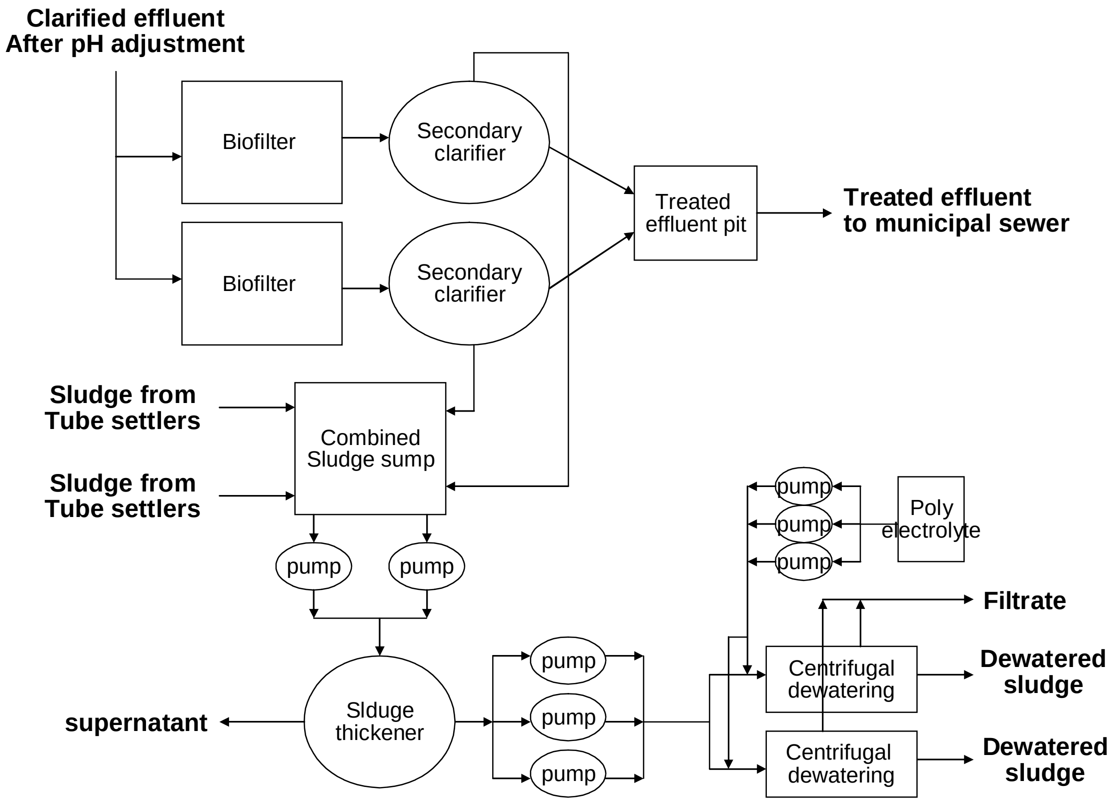

Figure-4.1: Wastewater Process of the CETP (contd..)

Table 4.1: Industrial units of the electroplating pocket

S.No.	**Activity**	**Number of units**
1.	Manufacturing of cycle parts	15 units
2.	Electroplating work	7 units
3.	Manufacturing auto parts	4 units
4.	Tampering work and hammer	3 units
5.	Manufacturing of paints and gums	3 units
6.	Fabrication of dye	2 units
7.	Manufacturing of cartoon boxes	2 units
8.	Knitting work	2 units
9.	Dyeing	2 units
10.	Cloth press	2 units
11.	Medical gas	1 unit
12.	Electrical wire	1 unit
13.	Ice work	1 unit
14.	Export work	1 unit
	Total units	46 units

Table-4.2: Dimensional and Other Details of the Facilities of the CETP

Facility	**Dimensional other details**
Wastewater recipient tank and raw effluent pumps	One bar screen of 80° inclination angle having 35 bars with 10 mm clearance between bars at the inlet section of the tank. Rectangular tank of 10 m length, 6.25 m width and 1.6 m liquid depth. Liquid storage capacity is 100 m^3 Four pumps each of 100 m^3/hour pumping capacity for pumping the wastewater from the recipient tank into the equalization tanks High liquid level and low liquid level sensors of the wastewater recipient tank for the operation and control of the pumps HDPE piping with necessary valves and other fittings for conveying the wastewater.
Grit and floating oil separation channels	Two channels (with common inlet and outlet chambers) each of 0.75 m width and 11.6 m length At the inlet end each channel has a gate valve and a bar screen The screen is inclined at 80° angle and has 35 bars with 10 mm clearance between bars Gate valve at the outlet of each of the channel for facilitating liquid level adjustment in the channel Each grit channel has a horizontal floating oil and grease collection draining facility. An oil pit for collecting the drained out oil and grease. Bottom drain provision at the mid length of the grit channel for facilitating degritting Grit dewatering pit with each of the grit channels with provision for recycling the wastewater overflows into the wastewater recipient tank Gate valves on the common outlet chamber of the grit channels to facilitate wastewater flow diverting into either of the two equalization tanks.

Table-4.2 (contd..)

Equalization tanks and effluent feed pumps	Two concrete equalization tanks each of 13.4 m length, 15 m width and 3.75 m liquid depth and of 750 m^3 wastewater storage capacity. Provision for diffused aeration mixing at the rate of 1.0 m^3/ m^3.hour. Three air blowers, each of 753.75 m^3/hour air supply capacity at 0.5 kg/cm2 delivery pressure. MS piping with necessary valves and other fittings for air supply to the eqaualization tanks Three pumps each of 100 m^3/hour capacity for pumping the wastewater from the equalization tanks into the neutralization tanks HDPE piping with necessary valves and other fittings for conveying the wastewater Higher and lower liquid level sensors in the two equalization tanks for the operation and control of the pumps
Neutralization tanks (Reaction tanks 1A and 1B)	Two RCC tanks each of 25 m^3 liquid holding capacity (3.5 m length, 3.25 m width and 2.2 m liquid depth and 0.3 m free board) with provisions for mechanical mixing. Provision for monitoring pH of the pH adjustment tank. Provision for regulated dosing of lime slurry and ferrous sulfate solution for the neutralization and metal precipitation. Two RCC (5% lime slurry preparation and dosing) tanks, each with 32 m^3 lime slurry storage capacity (3.6 m length, 3.6 m width and 2.5 m liquid depth and 0.3 m free board) Two centrifugal pumps and pvc piping with necessary valves and fitting and fresh water purging provisions for facilitating lime slurry dosing. Two RCC (10% ferrous sulfate solution preparation and dosing) tanks, each of 4 m^3 ferrous sulfate solution storage capacity (1.7 m length, 1.7 m width and 1.5 m liquid depth and 0.3 m free board) Three reciprocating positive displacement pumps and pvc piping with necessary valves and fittings and fresh water purging provisions for facilitating ferrous sulfate solution dosing.

Table-4.2 (contd..)

Tube settlers	Two tube settlers each of 8.1 m length, 2.7 m width and 2.2 m depth and 0.3 m free board. The tube settler is divided into three sections, each with a hoppered bottom of 60° slope. Tube settler medium of 1 m thickness in each of the sections at 0.6 m depth under the liquid. The tube settler with 16.2 m long clarified effluent over flow weir and 10.8 m long clarified effluent collection trough. Provisions (HDPE piping with necessary valves and other fittings) for draining out settled sludge from the hoppers of both the tube settlers into the combined sludge sump. Provision for regulated dosing of 0.5% polyelectrolyte solution into the neutralized wastewater inlet of both the tube settlers. Two CST (0.5% polyelectrolyte solution preparation and dosing) tanks, each with 1.6 m^3 polyelectrolyte solution storage capacity (1.3 m diameter and 1.4 m liquid depth and 0.3 m free board). Three reciprocating positive displacement pumps and pvc piping with necessary valves and fittings and fresh water purging provisions for facilitating polyelectrolyte solution dosing.
pH adjustment tanks (reaction tanks 2A and 2B)	Two RCC tanks each of 7 m^3 liquid holding capacity (2.15 m length, 2.15 m width and 1.5 m liquid depth and 0.3 m free board) with provisions for mechanical mixing. Provision for monitoring pH of the pH adjustment tank. Provision for regulated dosing of hydrochloric acid for adjusting pH of the clarified effluent. One CSRL tank of 0.6 m^3 capacity (0.8 m diameter and 1.2 m liquid depth and 0.3 m free board) for hydrochloric acid. Three reciprocating positive displacement acid pumps and pvc piping with necessary valves and fittings for facilitating ferrous sulfate solution dosing.

Table-4.2 (contd..)

Biofilter feed sumps and biofilter feed pumps	Two RCC tanks each of 35 m^3 liquid holding capacity (4.3 m length, 2.75 m width and 3.0 m liquid depth and 0.3 m free board). Provision for regulated dosing of nutrient solution into the clarified and pH adjusted wastewater inlet of both the biofilter feed sumps. Two CS tanks, each with 1.0 m^3 nutrient solution storage capacity (0.8 m diameter and 1.2 m liquid depth and 0.3 m free board). Two reciprocating positive displacement pumps and pvc piping with necessary valves and fittings and fresh water purging provisions for facilitating nutrient solution dosing. Three pumps each of 100 m^3/hour pumping capacity for pumping the wastewater from the biofilter feed sumps to the bio(trickling)filter. High liquid level and low liquid level sensors of the wastewater in the biofilter feed sumps for the operation and control of the pumps HDPE piping with necessary valves and other fittings for conveying the wastewater.
Bio(trickling)filters	Two bio (trickling)filters each includes the following: A bottom sump of 8.4 m length, 6 m width and 1 m depth for collecting the trickling wastewater Synthetic medium of 83 m^3 volume (7.2 m length, 4.8 m width and 2.4 m depth) Wastewater distribution network (of HDPE piping) with sprinklers over the top of the medium MS piping for conveying the trickled effluent collected in the bottom sump into the secondary clarifier.

Table-4.2 (contd..)

Secondary clarifiers	Two circular secondary clarifiers, each of 10 m diameter and 3 m side wall depth. The central well is used as inlet section and peripheral overflow weir and clarified effluent collection trough is outlet section for the clarifier. Central rotating mechanism for scrapping the settled sludge (on the sloping bottom) towards the center for removal through an underflow drain. Rectangular open channel for carrying the clarified effluent to a common chamber from where the effluent flows through a parshall flume into the municipal sewer. Provision for conductivity, pH, and turbidity and flow measurement prior to the treated effluent discharge into the municipal sewer. CI piping with necessary valves and other fittings for conveying underflow sludge into the combined sludge sump.
Combined sludge sump and sludge pumps	A single rectangular RCC tank of 60 m^3 sludge storage capacity (6 m length, 5 m width, and 2 m sludge depth and 0.3 m free board) with provision for mechanical mixing Two centrifugal pumps, each of 15 m^3/hour pumping capacity for pumping the sludge (1.5% consistency) from the combined sludge sump to sludge thickener. High liquid level and low liquid level sensors in the combined sludge sump for the operation and control of the pumps. MS piping with necessary valves and other fittings for conveying the sludge.

Table-4.2 (contd..)

Sludge thickener and thickened sludge feed pumps	One circular sludge thickener of 7.5 m diameter and 3 m sidewall depth. The central well is used as inlet section and peripheral overflow weir and supernatant collection trough is outlet section for the thickener. Central rotating mechanism for scrapping the settled sludge (on the sloping bottom) towards the center for removal through an underflow drain. Three screw pumps (each of 4.5 m^3/hour capacity) for pumping the underflow thickened sludge (4 to 5% consistency) to the centrifugal sludge-dewatering unit. MS piping with necessary valves and other fittings for conveying thickened sludge to the centrifugal sludge dewatering units. Necessary piping for conveying the supernatant of the thickener into an underground drain, which carries the effluent into the wastewater recipient tank.
Centrifugal sludge dewatering units	Two centrifugal sludge dewatering units each with a capacity to handle 4.5 m^3/hour of thickened sludge and dewater to 20% consistency level. Provision for regulated dosing of 0.5% polyelectrolyte solution into the thickened sludge inlet. One CST (0.5% polyelectrolyte solution preparation and dosing) tank of 1.5 m^3 polyelectrolyte solution storage capacity (1.2 m diameter and 1.4 m liquid depth and 0.3 m free board). Three reciprocating positive displacement pumps and pvc piping with necessary valves and fittings and fresh water purging provisions for facilitating polyelectrolyte solution dosing. Provisions for conveying the filtrate generated from the dewatering into an underground drain which also receives supernatant from the sludge thickener. Space for temporary storage of the dewatered sludge adjacent to the centrifugal sludge dewatering units.

Table 4.3: Capacity Assessment

Units and their Capacities	**Remarks**
Wastewater recipient tank with 4 raw effluent pumps each of 100 m^3/hour pumping capacity	If all the pumps are in working condition, assuming two pumps as standby 200 m3/hour is this units capacity. If three pumps can be kept in operation, it is possible to handle upto 300 m^3/hour wastewater.
Two Grit and floating oil separation channels (each of 0.75 m width and 11.6 m length)	The grit channels have no flow control sections and are designed for 100 m^3/hour flow per channel. Since horizontal flow velocity upto 0.4 m/sec. is tolerable increase, each of the girt channel can handle upto a maximum of 180 m^3/hour of flow. Hence the capacity available can be taken as 360 m^3/hour.
Two Equalization tanks (750 m^3 wastewater storage capacity) and three effluent feed pumps (each of 100 m^3/hour capacity)	With two pumps in operation, capacity of this facility is 200 m^3/hour. If the pumps available time can be increased, the operation can be either at 200 or 300 m3/hour depending on for how long the third pump can be operated.

Table-4.3 (contd..)

Two Neutralization tanks (Reaction tanks 1A and 1B) (25 m^3 liquid holding capacity) Two RCC (5% lime slurry preparation and dosing) tanks, each with 32 m^3 lime slurry storage capacity and Two RCC (10% ferrous sulfate solution preparation and dosing) tanks, each of 4 m^3 ferrous sulfate solution storage capacity	At 200 m^3/hour flow HRT of the neutralization tanks is 15 minutes. For neutralization, where homogenous mixing of the dosed chemicals is the need, this HRT is quite high. But, keeping in mind the flocculation required, capacity of this facility can be safely taken as > 100 m^3/hour per neutralization tank.
Two tube settlers, each of 8.1 m length and 2.7 m width and with 1.0 m thick tube settler medium and 16.2 m long clarified effluent over flow weir.	The sludge formed has been found to have very good settling properties and effective settling time of just 30 minutes has been found enough for giving the desired results. Conservatively assuming the available settling surface area as 5 times to the settling tank area and settling depth as 20 cm, each of the tube settler has over 200 m^3/hour capacity, while actual loading of the tube settler is around 100 m^3/hour.
Two pH adjustment tanks (reaction tanks 2A and 2B) (each of 7 m^3) and one CSRL tank of 0.6 m^3 capacity) for hydrochloric acid	At 200 m^3/hour flow HRT of these tanks is 4.2 min., while HRT of 3 minutes is considered as enough.
Two Bio-filter feed sumps (each of 35 m^3), three bio-filter feed pumps (each of 100 m^3/hour capacity), two CS nutrient solution tanks (each of 1.0 m^3 storage capacity) and nutrient solution dosing system.	Capacity of these facilities is quite sufficient to handle 200 m^3/hour flow. If not for the pumps, even larger flows can be handled by these facilities.
Two Bio (trickling) filters (each having 83 m3 volume of synthetic medium)	Secondary treatment of the wastewater has been found almost not needed and hence capacity assessment of the bio (trickling) filter has not been carried out. Even if secondary treatment is needed, the facility is quite sufficient for handling 200 m^3/hour flow.

Table-4.3 (contd..)

Two Secondary clarifiers (each of 10 m diameter and 3 m side wall depth.)	Settling properties of sludge from trickling filters is considered better than that from ASP. Further since sludge recycling is needed, the provided secondary clarifiers with HRT 3.56 hours at 200 m^3/hour flow are considered having the capacity to handle 200 m^3/hour flow.
One Combined sludge sump (60 m^3 sludge storage capacity) and two sludge pumps (15 m^3/hour pumping capacity)	Total sludge generation rate has been estimated at <4 m^3/hour. For handling this sludge capacity of these facilities is quite sufficient.
One Sludge thickener (7.5 m diameter and 3 m side wall depth) and three thickened sludge screw pumps (each of 4.5 m^3/hour capacity)	Since consistency of the sludge is already more than 4%, sludge thickener is considered redundant.
Two Centrifugal sludge dewatering units (each with a capacity to handle 4.5 m^3/hour of thickened sludge)	Since sludge generation rate is <4 m^3/hour, operation of only one of the two centrifugal sludge dewatering units is sufficient to handle the sludge generated.

CHAPTER 5: RESULTS

5.1 Introduction

Result of this study may be divided in to three parts

1. On-site performance evaluation studies
2. Performance evaluation studies in the TIET laboratories
3. Observation made at the time of detailed process mapping
4. Capacity Assessment

5.2 On-site performance evaluation studies

Ideally sampling for performance evaluation studies of the CETP might have been carried out when:

- The plant was in steady operation and treating at least 100 m^3/hour of equalized effluent
- The plant using at least one of the two streets of the treatment plant to its full capacity.

But in this CETP steady operation is absent and existing facilities for the preparation, storage and dosing of different treatment chemicals, specially, 5% lime slurry, 10% ferrous sulfate solution and hydrochloric acid, were not functional.

So made adhoc arrangements for dosing the treatment chemicals and stably operating the CETP for at least 5 hours duration for facilitating performance evaluation studies. In this arrangements made for dosing 5% lime slurry and hydrochloric acid. The arrangements made for dosing the lime slurry were found limiting and this forced to limit the loading of the equalized effluent to 45 m^3/hour (while requirement is at least 100 m^3/hour).

Since the existing CETP laboratory was not sufficiently commissioned for the necessary experimentation and estimation of required doses of different treatment chemicals, they neutralize the equalized wastewater to 9 to 9.5 pH with lime slurry and to adjust pH of the clarified effluent coming out from the tube settler to 7 to 7.5 pH with hydrochloric acid dosing.

After operating the CETP at 45 m^3/hour loading rate for three hours, and after pH adjustment (7 to 7.5 pH) of the clarified wastewater from the tube settler, the following four samples were collected half-hourly over two hour period and composite samples were prepared. Analysis results are given in table-5.1

- Raw wastewater pumped from the raw wastewater recipient tank
- Equalized wastewater being pumped to the neutralization tank (reaction tank-1)
- Clarified effluent coming out from the tube settler prior to pH adjustment with hydrochloric acid
- Final effluent after secondary clarification prior to discharging into the municipal sewer

All the sludge handling facilities of the CETP were operated but no sludge samples were collected because the doses of the chemicals (lime slurry and hydrochloric acid) applied were not known so such samples was felt will not be representative.

5.3 Performance evaluation studies in the TIET laboratories

And, Keeping these limitations of the on-site performance evaluation study, necessary experimentations were carried out in the Environmental laboratory of Thapar Institute of Engineering and Technology. These samples are:

1. Equalized wastewater collected from the CETP
2. Effluent after neutralization with lime and settling
3. Effluent after neutralization, coagulation, flocculation and settling treatment with lime slurry and ferrous sulfate solution

From the experiments carried out in the laboratory, the above three samples were collected and analyzed for finding the answers of the following questions:

1. What is the optimum pH to which the equalized wastewater should be neutralized and what will be the required lime dose?
2. To what extent dosing of ferrous sulfate will improve the treatment process? And what is the optimum dose for ferrous sulfate?
3. Is there really a need for the dosing of polyelectrolyte?
4. How much sludge will be generated from the neutralization, coagulation, flocculation and settling treatment of equalized wastewater?
5. Is there really a need for the secondary treatment of the clarified effluent coming out from the tube settlers for complying with the effluent standards?

Analysis results of the samples collected from the CETP during evaluation studies are shown in **table-5.1 & 5.2**. Experimentation in the TIET laboratory indicated that Equalized wastewater collected from the CETP required optimal pH for the precipitation removal of metals and colloidal and suspended solids was 9.0 and lime dosing required was 160 mg/l. When the effluents were neutralized to this pH the sludge formed was 571 g/m^3 (sludge volume was 6.5 liters/m^3 after 30 minutes of settling). Dosing of ferrous sulfate into the neutralized effluent at the rate of 30 mg/l had dramatically improved the treatment efficiency (turbidity of the treated effluent was reduced from 125 to 7 NTU). Sludge generation from ferrous sulfate dosing had increased to 647 g/m^3 (sludge volume was 10 liters/m^3 after 30 minutes of settling). HCl consumption for adjusting pH of the clarified effluents was estimated at 53 grams/m^3 as 100% pure acid.

On the basis of loading rate (200 m^3/hour) of the equalized effluent 32 kg/hour lime is consumed for neutralization of effluent to 9 pH when the lime purity is 81.4%. Ferrous sulfate consumption in the coagulation and flocculation is 6 kg/hour for improving the settling property. 10.6 kg/hr. pure acid (Hcl) is used for pH adjustment of clarified effluent after neutralization, and coagulation and flocculation to 7 pH. Sludge generated when only lime is dosed is 114.2 kg and volume and consistency of the sludge generated is 1.3 m^3/hour (8.7%). Sludge generated when both lime and ferrous sulfate were dosed is 129.4 kg and volume and consistency of the sludge generated is 2.0 m^3/hour (6.47%).

Please see **table-5.3** for details expressed in terms of treatment of 200 m^3/hour of equalized effluent.

5.4 Observation made at the time of detailed process mapping

At the time of detailed process mapping CETP is run on the power generated by a dedicated DG set. But this may prove the effluent treatment very costly. For minimizing the cost it is advisable to have provision for PSEB grid power.

Inlet screen gets submerged in the raw effluent sump and this leads to mixing of the separated screenings into the raw effluent. These screenings must be affecting pumping of the raw wastewater into the grit channels.

Raw effluent pumps were found frequently tripping. This is necessitating deputing one operator at the panel of the pumps to switch on the pumps whenever they trip. Remixing of the screenings with the wastewater in the wastewater recipient tank and use of submergible jet pumps rather than centrifugal pumps must be responsible for this problem.

Floating oil and grease separated from the grit channels is collected into a pit provided under the grit channels and this pit is found overflowing and flooding the premises whenever the oil separation is carried out. There is no provision for concentrating the oil separated and for recycling the effluent (generated from such concentration process) back into the raw effluent sump.

Lime and ferrous sulfate are being dosed into the reaction tanks- 1A and 1B for the neutralization and precipitation of metals from the equalized effluents. This makes control of lime and ferrous sulfate doses and matching with the effluent flow rate very difficult, and precipitation removal of metals not very efficient. Further, this approach does not allow efficient precipitation removal of ferrous metal from the effluent (ferrous metal is not sufficiently insoluble). Further, the treated effluent, when loaded to the bio(trickling)filter, because of coming in contact with atmospheric oxygen, can turn to red in colour from the conversion of ferrous iron into ferric iron and precipitation. In addition to these, iron concentration in the treated effluent can be higher and causing non-compliance with the prescribed standards.

Controlled dosing of lime and ferrous sulfate cannot be possible because of the pipeline clogging problems. In case of the lime slurry, the pipeline is clogging may be because of many bends and a raiser section. At these bends and in the riser section the suspended lime and impurities must be settling and causing clogging. Throttling of lime slurry discharge into the reaction tank may further increase the risk of clogging. All the efforts to frequently purge the pipeline with fresh water have been failures in solving the clogging problem. In case of ferrous sulfate, mechanical mixing of the prepared ferrous sulfate solution present in the dosing tank must be converting the ferrous iron into ferric iron and forming precipitates. These precipitates along with the impurities of the ferrous sulfate must be causing the clogging problem. In this case also, frequent purging with fresh water has been found ineffective in removing the clogs. Consequence of this inability, to dose the chemical solutions at desired rate, is inefficient removal of metals from the effluent. Sludge drain of the tubular settling unit may be clogged because self cleaning velocity can not be maintained in this relatively larger diameter underground drain having a raiser section. As a consequence removal of the settled sludge from the tubular settling unit can become a problem.

Provisions for dosing the polyelectrolyte are wrongly made. The ployelectrolyte is actually dosed into the outlet of the tube settlers rather than into the inlet of the tube settler.

Presently fresh water supplied by the municipality at the cost of Rs. 5 per kL is used for preparing lime slurry, and ferrous sulfate and other chemical solutions. In place of the fresh water, treated effluent can be used for the preparation of these chemical solutions. This can conserve water and reduce the expenses associated with the purchase of water.

With the arrangements for operating the CETP not continuously it may become difficult to ensure continued loading of the bio(trickling)filters which is essential for ensuring moist viable biofilm on the synthetic medium of the bio(trickling)filters.

There is an ETP laboratory but it is not sufficiently commissioned and it cannot be used either for monitoring the treatment process or for conducting the experiments relating to the estimation of optimum dose of various treatment chemicals.

Table-5.1: Results obtained from the analysis of samples collected from the CETP

Parameter	**Raw effluent**	**Equalized effluent**	**Clarified effluent after neutralization to 9 to 9.5 pH**	**Treated effluent prior to disposal into municipal sewer**
pH	7.13	7.26	9.36	7.72
Conductivity	1.758	1.871	1.622	1.527
Total solids, TS (mg/l)	1485	1405	1135	1120
Total dissolved solids, TDS (mg/l)	1240	1295	1095	1050
Total suspended solids, TSS (mg/l)	245	110	40	70
Oil and grease (mg/l)	41	NA	NA	8.4
COD (mg/l)	400	325	262.5	162.5
BOD_5 at 20°C (mg/l)	115.5	79.6	62.7	35.2
Ammonical-N (mg/l)	2.128	1.512	2.128	1.624
Organic-N (mg/l)	1.904	1.12	0.896	0.616
Nitrate-N (mg/l)	0.487	0.487	0.489	0.372
Nitrite-N (mg/l)	0.020	0.018	0.021	0.061
Phosphate (mg/l)	0.089	0.209	0.062	0.096
Phenolic compounds	BDL	BDL	BDL	BDL
Cyanide (mg/l)	1.3	NA	NA	1.0
Iron (mg/l)	32.4	11.1	6.27	9.4
Zinc (mg/l)	3.16	1.23	0.61	1.41
Nickel (mg/l)	0.97	0.44	0.41	0.45
Hex. chromium (mg/l)	BDL	BDL	BDL	BDL
Total chromium (mg/l)	0.77	0.82	1.06	0.5
Manganese (mg/l)	0.31	0.24	0.13	0.26
Copper (mg/l)	0.12	0.14	0.21	0.26
Lead (mg/l)	0.16	0.08	0.10	0.10
Cadmium	BDL	BDL	BDL	BDL
Mercury (mg/l)	BDL	BDL	BDL	BDL

Table-5.2: Results obtained from laboratory neutralization and coagulation, flocculation and settling experiments on equalized wastewater

Parameter	**Wastewater from equalization tank**	**Clarified effluent after neutralization to 9 pH with lime**	**Clarified effluent after neutralization to 9 pH and optimum doising of ferrous sulfate**
Total dissolved solids, TDS (mg/l)	1320	1160	1160
Total suspended solids, TSS (mg/l)	350	170	70
COD (mg/l)	480	240	100
BOD_5 at 20°C	70.2	49.5	28.05
Ammonical nitrogen	3.248	3.248	3.136
Organic nitrogen	3.024	2.576	2.128
Iron	29.3	25.9	10.5
Zinc	5.12	3.22	0.75
Nickel	1.0	0.91	0.46
Hexavalent chromium	BDL	BDL	BDL
Total chromium	1.5	1.7	1.18
Manganese	0.64	0.47	0.36
Copper	0.16	0.15	0.30
Lead	0.08	0.05	0.16
Cadmium	BDL	BDL	BDL
Mercury	BDL	BDL	BDL

Table-5.3: Chemical dosing required and sludge generation rates for the neutralization, coagulation, flocculation and settling of equalized effluents

Loading rate of the equalized effluent	200 m^3/hour
pH of the equalized effluent	7.55
Purity of the lime used	81.4%
Lime consumption for neutralization of effluent to 9 pH	32 kg/hour
Ferrous sulfate consumption in the coagulation and flocculation of the effluent neutralized to 9 pH	6 kg/hour
Hydrochloric acid consumption for pH adjustment of clarified effluent after neutralization, and coagulation and flocculation to 7 pH	10.6 kg/hr. as pure acid
Sludge generated when only lime is dosed	114.2 kg
Volume and consistency of the sludge generated	1.3 m^3/hour (8.7%)
Sludge generated when both lime and ferrous sulfate were dosed	129.4 kg
Volume and consistency of the sludge generated	2.0 m^3/hour (6.47%)

CHAPTER 6: DISCUSSION AND RECOMMENDATIONS

6.1 Discussion of results

After evaluating the analysis result except for iron, treated effluent is by and large complying with the effluent standards prescribed. Comparison of the results of analysis of the treated effluents (given in the tables) with the standards given in **table-6.1** indicates non-compliances with respect to BOD and cyanide as well, as shown below:

	BOD_5 at 20°C	**Cyanide**	**Iron**
Treated effluent prior to disposal	35.2 mg/l (30 mg/l)*	2.0 mg/l **	9.4 mg/l (3mg/l)
Effluent after neutralization, coagulation, flocculation and settling (lab experiment)	28 mg/l	---	

*: Values given in the parenthesis are the standards prescribed, but applicable for the effluent being discharged into surface water bodies (not into the public sewers). The CETP is actually discharging its treated effluent into public (municipal) sewer. For disposal into the municipal sewer, according to the General Standards, Schedule-6 of the Environmental (Protection) Rules, 1986, BOD_5 at 20°C of the effluent can be upto 100 mg/l.

** The CETP in question has no provisions for taking care of cyanide pollution and the CETP is not supposed to take care of the cyanide pollution. The industrial units are supposed to segregate the cyanide containing wastewaters pre-treat and then allow them into the CETP.

The performance evaluation studies indicate non-compliance with respect to iron content in the treated effluent. Laboratory experiments indicated use of ferrous sulfate in the treatment process would further increase the iron concentration in the final effluent. Ferrous iron is soluble and cannot be efficiently removed from the effluent during treatment. However, sufficient aeration can oxidize the ferrous iron of the effluent into ferric iron (which is less soluble and form reddish brown flocs), and this in-turn can be removed during the flocculation and settling. Aeration of the neutralized and coagulated effluent prior to sending into the tube settlers for clarification can ensure efficient removal of iron and compliance with the prescribed effluent standard (3 mg/l) for iron.

Optimum pH for neutralization, coagulation, flocculation and settling treatment has been found to be 9.0. Dosing of ferrous sulfate to the neutralized effluent was found by and large improving the treatment efficiency. This is evident from the review of the results given in **table-5.2**. Further, since the effluent treated in the CETP has mild colour stinge (may be because of the effluents from dying units), coagulation and flocculation of the effluent with ferrous sulfate may be needed.

Laboratory studies indicated that the flocs formed from neutralization and coagulation and flocculation have very good settling properties. Half an hour settling of the effluent, without using any ployelectrolyte as a coagulant aid, is resulting in the generation of 6.5% consistency sludge. This indicates that dosing of polyelectrolyte into the inlet of the tube settler may not be required. However, polyelectrolyte dosing into the sludge for dewatering may be needed.

Assumed consistency of secondary sludge from the secondary clarifiers of the bio(trickling)filters as 1.5 and secondary sludge generation rate as <15 kg/hour, combined sludge generation rate from the treatment of 200 m^3/hour of effluent is 145 kg/hour (3 m^3/hour of volume) and consistency of the combined sludge may be about 4.8%. A conservative estimate of consistency is 4% and combined sludge volume is 3.625 3 m^3/hour. This indicates that the combined sludge can (without any thickening in the sludge thickener) directly be loaded to the centrifugal dewatering units.

Laboratory experimentation indicates that neutralization, coagulation, flocculation and settling may be sufficient for complying with the applicable BOD and COD effluent standards, even for discharging the treated effluent into surface water bodies. Coagulation and flocculation of the neutralized effluent with ferrous sulfate has been shown to increase BOD and COD removal efficiencies from 31% and 50% to 60% and 79% respectively. This indicates that clarified effluent coming out from the tube settlers may not require any secondary treatment in the bio (trickling) filters for complying with the prescribed effluent standards. If the secondary treatment can be avoided, the clarified effluent coming out from the tube settler may not require any pH adjustment and it can directly be discharged into the municipal sewer. This, as a fringe benefit, can minimize or even eliminate the hydrochloric acid need of the CETP.

6.2 Recommendations

1. For avoiding frequent tripping of raw effluent pumps because of clogging, effluent level in the raw effluent tank may always be maintained below the walkway to the bar screen in the tank. If this is not feasible, bar screen chamber may be separated from the raw effluent tank by raising the walls. Further, suction ends of the pumps may be enclosed in wire mesh. Use of submergible pumps for lifting raw effluent might have actually been avoided.
2. The oil pit associated with the grit channels may be modified to include provision for draining out the water (drawn along with the oil from the grit channels), while retaining the oil within, and conveying the water into the raw effluent sump. For this the oil pit similar to septic tank can be provided.
3. Treated effluent is not complying with the standards prescribed for iron. This could be because of non-conversion of ferrous iron into ferric iron. Conversion of ferrous iron to ferric iron can occur if the effluent is made alkaline and aerated. It appears that the aeration occurring in the trickling filter is not sufficient. For ensuring the compliance provision may be made for the aeration of the effluent after neutralization and precipitation through dosing lime slurry and ferrous sulfate. If feasible dosing of lime slurry and ferrous sulfate into the equalization tank filled with the effluent, then aeration of the effluent and then pumping the effluent directly to the tube settler may be practiced.
4. Despite duplication and triplication of pumps dosing of treatment chemicals specially, lime slurry and ferrous sulfate solution is a problem because of clogging of piping. For tackling this problem lime slurry and ferrous sulfate solution preparation tanks may be located closer to the neutralization and dosing may be made feasible under gravity flow.

5. Bio(trickling)filter is not be needed for the treatment of the effluent. Hence the bio(trickling)filters may be bypassed. This can reduce cost of treatment through avoided pumping of effluent through the filters, and avoided consumption of HCl for pH adjustment.

6. The existing facilities are wrongly dosing polyelectrolyte into the outlet of the tube settlers. This needs correction and the dosing should be into the inlet of the tube settlers. Performance of the tube settlers and laboratory experimentation has indicated that polyelectrlyte dosing is not actually required. The sludge generated has been found to have very good settling properties. Hence, polyelectrolyte dosing may be practiced only if needed.

7. Sludge generated has been found to have consistency much higher than what is required by the centrifugal dewatering units. Hence, the sludge thickener may also be bypassed and the generated sludge may directly be loaded to the dewatering units. This can reduce the treatment costs through avoiding pumping of sludge and through the avoided operation of the thickener.

8. Significant quantity of the costly municipal water is consumed in the preparation of ETP chemical solutions (specially lime slurry and ferrous sulfate solution). For conserving water and reducing cost, treated final effluents may be used in place of the municipal water in the preparation of the ETP chemical solutions. This for the preparation of dosing chemical solutions.

9. Currently a DG set of 270 KVA capacity is used for supplying power to the CETP. DG power is quite costly, and hence, PSEB grid power may be used to run the ETP and use DG power may be used as a standby arrangement.

10. The CETP has been suffering from lack of laboratory facilities, trained lab analyst and skilled operators. The existing CETP laboratory may be properly commissioned, necessary trained staff may be employed and the already employed operator(s) may be appropriately trained for ensuring proper operation and control of the CETP. Further, the CETP may have necessary arrangements and understanding with local outside organization for the maintenance of the CETP.

Table-6.1: Parameters chosen for the performance evaluation and standards prescribed for them

Parameter	**CETP#**	**Electroplating@**
pH	5.5 – 9.0	6.0 – 9.0
Conductivity	---	---
Total solids, TS (mg/l)	---	---
Total dissolved solids, TDS (mg/l)	2100	---
Total suspended solids, TSS (mg/l)	100	100
Oil and grease (mg/l)	10	10
COD (mg/l)	250	---
BOD_5 at 20°C (mg/l)	30	---
Ammonical-N (mg/l)	50	50
TKN (mg/l)	100	---
Nitrate-N (mg/l)	---	---
Nitrite-N (mg/l)	---	---
Phosphate (mg/l)	---	---
Phenolic compounds	10	---
Cyanide (mg/l)	0.2	0.2
Iron (mg/l)	---	3.0
Zinc (mg/l)	5.0	5.0
Nickel (mg/l)	3.0	3.0
Hex. chromium (mg/l)	---	0.1
Total chromium (mg/l)	2.0	2.0
Manganese (mg/l)	---	---
Copper (mg/l)	3.0	3.0
Lead (mg/l)	0.1	0.1
Cadmium	1.0	2.0
Mercury (mg/l)	0.01	0.01

#: standards applicable when the discharge is into surface waters. Adopted from entry-55 of Schedule-1 of EP Rules, 1986

@: standards adopted from entry-9 of Schedule-1 of EP Rules, 1986.

CHAPTER 7: CONCLUSIONS

The CETP in question is by and large complying with the standards prescribed. Only exception is iron and even this can be easily complied with. The CETP is found over designed. It can treat >200 m^3/hour of effluent, while the effluent generation rate may not cross 100 m3/hour. The CETP is superfluous. Bio(trickling)filters, secondary clarifiers and sludge thickener are not actually needed. More than required pumps provided at many places. No efforts were made to make the CETP energy efficient. All these might have made the capital investment high and even the operational costs must also be high. The existing ETP chemical solution preparation, storing and dosing systems are not properly designed and regulated dosing of treatment chemical solutions is a serious problem encountered by the CETP.

The study has brought into light the following additional problems relating to the success of the CETPs:

- Design of the CETP was not based on sufficient background information about the industrial units contributing the wastewater and it apparently was not supported by proper treatability studies.
- Lack information about the activities of the contributing industrial units and about the quantities and characteristics of the wastewater they contribute. In the absence of this information ensuring necessary pre-treatment, regulation of effluent discharge by individual industrial units, and charging individual industrial units for their effluent treatment difficult.
- Non-availability of trained manpower for the operation and control of the CETP.

Third party review of the design prior to approval for erection and commissioning of the CETP can also contribute significantly to the success of CETPs.

REFERENCES:

1. APHA, AWWA and WPCF (1995), “Standard methods for the Examination of water and wastewater”. 19th edition, jointly edited by Eaton, A.D.; Clesceri, L.S. and Greenberg, A.E.
2. Braum, D. (2004), “Implementation of hybrid pollution control techniques to regulate the metal finishing industries in the Ethekwini Municipality”.*Water SA*, Vol. 30, No. 5 (Special edition) ISSN 0378-4738 http://www.wrc.org.za.
3. CPCB. (2001), “Common Effluent Treatment Plants”. Parivesh Newsletter, January 2001, Central Pollution Control Board, Delhi.
4. Crear, R. (2001), “Engineering and design precipitation/coagulation/flocculation”. Department of the army (U.S. army corps of engineers), Manual No. 1110-1-4012, EM 1110-1-4012
5. Christie, W.N. (1998), “In Industrial Waste Stream Generation”. Prentice Hall, New Jersey.
6. Dasgupta, N. (2000), “Environmental enforcement and small industries in india: reworking the problem in the poverty context”. *World Development* Vol. 28, No. 5, pp. 945±967,
7. Eckenfelder, W.W. Jr. (2000), “Industrial Water Pollution Control”. McGraw Hill, Boston.
8. El-Mallah, A.T. and Younan, M.M. (2001), “Environmentally Sound Technology in Metal Finishing”
9. EPA. (1990), “Guides to Pollution Prevention: The Fabricated Metal Products Industry”. pp.8, 9, 24, 28 and 29.
10. EPA. (1995), “Treatment of Metal Wastestreams: A field study-training program”. 2nd ed., ISBN1-884701-07-8.
11. EPA. (1996), "International Waste Minimization Approaches and Policies to Metal Plating”. EPA530-R-96-008.
12. EPA. (1998), “Profile of the Aerospace Industry: Office of Compliance Sector Notebook Project”. EPA310-R-98-001.
13. ESCWA. (2001), “Environmentally sound technologies in the Metal Finishing Industry”. United Nations, New York.

14. Eswaramoorthi, S.; Dhanapal, K. and Karpagam, J. (2004), “Zero Discharge - Treatment Options for Textile Dye Effluent: A Case Study at Manickapurampudur Common Effluent Treatment Plant, Tirupur, Tamil Nadu”. EPIC India, No.33, Anugraha Gardens, Singanallur, Coimbatore-641005, India
15. Freeman, H.M. (1995), “Industrial Pollution Prevention Handbook”. McGraw Hill, Inc., New York. ISBN 0-07-022148-0
16. Goldar, B.; Misra, S. and Mukherji, B. (2001), “Water pollution abatement cost function: methodological issues and an application to small-scale factories in an industrial estate in India”. *Environment and Development Eco*nomics vol. 6: 103–122
17. Hanford Pollution Prevention [HPP]. (2000), “Success Stories Blasting System’. Department of Energy, United States of America, URL: http://www.hanford.gov/polprev/fy95/36.htm, date (9/11/2000).
18. Kathuria, V. (2003), “Failure of Collective Action as an Institution – Lessons from Kundli, Haryana”. Institute of Economic Growth, Delhi,
19. Kurian, J. (2000), “Studies on Hosiery Textile dyeing Effluents for minimization of Total Dissolved Solids by Low Salt Dyeing at Low Liquor Ratio and Decolourisation by Physico chemical Treatment”. Ph.D Thesis, Centre for Environmental Studies, Anna University, Chennai.
20. Kurian, J. (2004), “A cleaner production approach for minimization of total dissolved solids in reactive dyeing effluents". Centre for Environmental Studies, Anna University, Chennai.
21. Labunska, I.; Stephenson, A.; Brigden, K.; Santillo, D.; Stringer, R.; Johnston, P.A. and Ashton, J.M. (1999), “Organic and heavy metal contaminants in samples taken at three industrial estates in Gujarat, India”. Greenpeace Research Laboratories Exeter 1999
22. Mack, C.; Burgess, J.E. and Duncan, J.R. (2004), “Membrane bioreactors for metal recovery from wastewater: A review” *Water SA* Vol. 30, No. 4 ISSN 0378-4738 http://www.wrc.org.za
23. Maheswari, M. and Dubey, S. (2000), “Common Effluent Treatment Plant A solution or a problem in itself” Toxics Link (a non profit environmental organization)

24. Metcalf & Eddy Inc. (1979), “Wastewater Engineering: Treatment, Disposal & Reuse”. 2nd Edition, McGraw Hill, New York.
25. Metcalf and Eddy. (1991), “Wastewater Engineering: Treatment, disposal, and reuse”. McGraw-Hill, Inc., Singapore.
26. Ministry of Environment and Forests (MOEF). (2003), “Hazardous Wastes (Management and Handling) Amendment Rules 2003”. S.O.593 (E),[20/5/2003]
27. Ministry of Environment and Forests (MOEF). (2000), “Noise Pollution (Regulation and Control) Rules 2000”. S.O.123 (E), [14/2/2000]
28. Ministry of Environment and Forests (MOEF). (1986), “The Environment (Protection) Rules, 1986”. S.O.844 (E), [19/11/1986].
29. Ministry of Environment and Forests (MOEF). (2004), “The Environment (Protection) Second Amendment Rules 2004” G.S.R.448 (E), [12/07/2004]
30. Ministry of Environment and Forests (MOEF). (2000), “The Hazardous Wastes (Management and Handling) Amendment Rules, 2000” S.O.24 (E), [6/1/2000]
31. Ministry of Environment and Forests (MOEF). (1989), “The Manufacture, Storage and import of Hazardous Chemical Rules, 1989”. S.O.966 (E), [27/11/1989]
32. Ministry of Environment and Forests (MOEF). (2000), “The Manufacture, Storage and Import of Hazardous Chemical (Amendment) Rules, 2000”. S.O.57 (E), [19/1/2000]
33. Ministry of Environment and Forests (MOEF). (1974), “The Water (Prevention and Control of Pollution) Act, 1974, amended 1988”. No.6 of 1974, [23/3/1974]
34. Ministry of Environment and Forests (MOEF). (1977), “The Water (Prevention and Control of Pollution) Cess Act, 1977, amended 1992”. No.36 of 1977, [7/12/1977]
35. Ministry of Environment and Forests (MOEF). (2003), “The Water (Prevention and Control of Pollution) Cess (Amendment) Act, 2003”. No. 19 of 2003, [17/3/2003]
36. Ministry of Environment and Forests (MOEF). (1974), “The Water (Prevention and Control of Pollution) Act, 1974, amended 1988”. No.6 of 1974, [23/3/1974]
37. Ministry of Environment and Forests (MOEF). (1989), “The Hazardous Wastes (Management and Handling) Rules, 1989”. S.O.594 (E), [28/7/1989]

38. National Environment Policy. (2004), Ministry of Environment and Forests, Government of India, New Delhi (Draft).
39. NEWMOA: The Northeast Waste Management Officials' Association, Pollution Prevention for the Metal Finishing.
40. Pathe, P.P.; Kumar, S.; Kharwade, M.; and Kaul, S.N. (2004), "Common Effluent Treatment Plant (CEPT) for Wastewater Management from a Cluster of Small Scale Tanneries". *Environmental Technology*, Volume 25, Number 5, pp. 555-563 (9).
41. Phungrassami, H. (2001), "Development of an integrated environmental action plan for chromalloy (Thailand) Ltd.". Asian Institute of Technology School of Environment, Resources and Development Bangkok, Thailand
42. Pophali, G. R.; Kaul, S. N. and Mathur, S. (2003), "Influence of hydraulic shock loads and TDS on the performance of large-scale CETPs treating textile effluents in India" *Water Reaserch* volume37 issue 2 Pages 353-361
43. Prasad B.M. (2000) "An overview of CETP's in India". CPCB, Delhi.
44. Ramakrishna1, V. and Babu, B. V. (2000), "Positive Decision Making in Waste Management towards Achieving Sustainable Development". Birla Institute of Technology & Science, Pilani, Rajasthan, India. http://bvbabu.50megs.com
45. Sankar, U. (2000), "common effluent treatment plants: an institutional arrangement for pollution control in small-scale tanneries in India". Madras school of Economics Allied Publishers, New Delhi.
46. Sankar, U. (2001), "Economic Analysis of Environmental Problems in Tanneries and Textile Bleaching and Dyeing Units and Suggestions for Policy Actions". Allied Publishers, New Delhi.
47. Suzuki, Y.; Mochidzuki, K.; Takeuchi, Y.; Yagishita, Y.; Fukuda, T.; Amakusa, H. and Abe, H. (1996), "Biological activated carbon treatment of effluent water from wastewater treatment processes of plating industries". *Separations Technology*, Volume-6, Issue 2, pp 147-153.
48. Tare, V.; Gupta, S. and Bose, P. (2003), "Case Studies on Biological Treatment of Tannery Effluents in India". Environmental Engineering and Management Program, Department of Civil Engineering, Indian Institute of Technology, Kanpur, India *J. Air & Waste Manage. Association*. vol 53: 976–982, ISSN 1047-3289

49. Theodore, L. and McGuin, Y.C. (1992), “Pollution Prevention”. Van Nostrand Reinhold, New York.
50. Wang, L.K and Sung Wang, M.H. (1992), “Handbook of Industrial Waste Treatment”. Volume 1. Marcel Dekker, Inc., New York.
51. Watson, M.R. (1973), “Pollution Control in Metal Finishing”. Noyes Data Corporation: ISBN 0-8155-0505-1, pp.4, 11, 12, 195 and 197.
52. World Bank. (1991), “Industrial Pollution Control Projects, India: Feasibility Assessment of Common Treatment Facilities in Gujarat, Maharashtra and Tamil Nadu”. Prepared for the World Bank by Chemcontrol A/S, Denmark.